Regional Wave Propagation Characteristics in China and Southern Asia

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Abstract

Regional wave propagation studies are currently an important focus of research because of concerns over proliferation of nuclear weapons. Regional studies serve a twofold purpose: (1) regional data can provide stable yield estimates for underground nuclear explosions, and (2) regional data can discriminate between explosions and earthquakes. Yield and discrimination studies have often used the Sn and Lg regional phases. However, discriminants based on these types of regional data are generally not transportable and must be individually calibrated for a particular region. For China and Southern Asia the problem has been a lack of recorded local and regional events. The first step to alleviate this problem is to increase the database of regional seismic data and their associated ground truth information. To achieve this goal we have documented the regional waveform characteristics of bandpassed (0.5 -5 Hz) digital data collected by the Chinese Digital Seismic Network (CDSN). Our current work has concentrated mostly on mapping Sn and Lg propagation efficiencies, especially beneath the continental plateaus.

The northern Tibet Plateau seems to attenuate most Sn, but southern and eastern Tibet often have weak, but visible, Sn propagation. Sn also does not propagate efficiently beneath the Mongolian Plateau, southeast China, the Baikal Rift, the east China Rift, and Indochina. Events occurring on the Pacific Rim also lack the Sn phase. Paths of efficient Sn propagation exist in central China , in northeast China, and within the Tarim Basin and the Tien Shan. With some notable exceptions, we observe, then, that Sn seems to be attenuated for most tectonically active regions (Tibet, Mongolia, Indochina, the east China Rift, and the west Pacific), while it is not attenuated within the more stable regions of eastern China. Since Sn is often attenuated where Pn velocities are low, we conclude that a small amount of partial melt within the mantle may be responsible for much of the Sn attenuation within Asia. Alternatively, a very thin mantle lid with a negative S-velocity gradient could also diminish Sn.

Lg propagates efficiently for ray paths that are nearly perpendicular to the Himalayas, but it is rapidly attenuated for paths traveling parallel to the mountain range. Lg does, however, propagate well for paths within the Tien Shan and the Tarim Basin. Within the Tibetan Plateau, Lg is observed for paths with distances less than about 6 degrees. Lg is highly attenuated when ray paths cross western or northern Tibet, the eastern Himalayan Syntaxis or Indochina. Lg propagates well for northeast and north central China as well as Mongolia. Lg propagates efficiently across the Taiwan strait, but is clearly attenuated for all raypaths crossing any oceanic crust. In general, Lg is seen more often than Sn. Our observations are consistent with Lg being attenuated primarily by rapid variations in crustal structure such as changes from continental crust to oceanic crust. Crustal changes across the Himalayan front are not enough to fully attenuate Lg unless a substantial portion of the Himalayas is crossed.

Key words: China, Tibet, Sn, Lg, attenuation.

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Objective

Regional wave propagation studies are currently an important focus of research because of concerns over proliferation of nuclear weapons. Regional studies serve a twofold purpose: (1) regional data can provide stable yield estimates for underground nuclear explosions, and (2) regional data can discriminate between explosions and earthquakes. Yield and discrimination studies have often used the Sn and Lg regional phases. However, discriminants based on these types of regional data are generally not transportable and must be individually calibrated for a particular region. For China and Southern Asia the problem has been a lack of recorded local and regional events. The first step to alleviate this problem is to increase the database of regional seismic data and their associated ground truth information. To achieve this goal we have documented the regional waveform characteristics of bandpassed (0.5 -5 Hz) digital data collected by the Chinese Digital Seismic Network (CDSN) (Figure 1). Our current work has concentrated mostly on mapping Sn and Lg propagation efficiencies, especially beneath the continental plateaus. We are interested in the relationship between the propagation of these phases and regional tectonics.

Research Accomplished

The character of Pn, Pg, Sn and Lg propagation was used to constrain structure and provide insights into the tectonic processes, most notably in structurally complex areas such as the Middle East, Central Asia and the Tibetan Plateau (Ruzaikan et al., 1977, Kadinsky-Cade et al., 1981, Ni and Barazangi, 1983, 1984). In these studies short-period analog seismograms were used to qualitatively characterize broad tectonic provinces and subprovinces in terms of either efficient or inefficient Sn and Lg propagation. Quantitative analysis of the Lg phases and the Pnl phase was also conducted (e.g. Kennett 1986; Xie and Lay, 1994). Our approach to documenting the characteristics of observed regional phases is empirical. When propagation paths cross some tectonic regions, the amplitudes of particular regional phases are dramatically reduced.

During the past year we have nearly completed analyzing regional wave propagation characteristics from broadband data recorded by the CDSN stations (Figure 1). We examined over 8000 seismograms. Sn and Lg propagation efficiencies from regional events to each station are mapped. These maps rank Sn and Lg propagation efficiency based on the amplitude of Sn or Lg relative to Pn: "A" classification is for very efficient propagation where the amplitude of either Sn or Lg is similar to or larger than half the amplitude of the Pn wave; "B" classification is for attenuated Sn or Lg phases with amplitudes less than half that of the Pn wave; "C" classification is used when Sn or Lg are not observed. We present results from eight CDSN stations.

For station LSA (Lhasa; Figure 2), Sn propagates efficiently across the Himalayas. In contrast, Sn does not propagate through a large portion of the central and northern Tibet. In southern Tibet, Sn propagation efficiency is reduced when compared with those traversing

mainly the Himalayas. Lg does not propagate efficiently (B and C classification) across the Himalayas when the ray path is subparallel to the Himalayas; however, Lg is observed for those ray paths that are more perpendicular to the strike of the mountain belt. Within the Tibetan Plateau, Lg is observed only for paths with distances less than about 6 degrees. We also observed that the Indus Tsangpo Suture attenuates most crustal phases. The attenuation is probably due to a partially melted upper crust rather than the complex structure in the suture.

For station WMQ (Urumqi; Figure 3), Sn is observed from crustal events originating in the western Himalayas, the Pamirs and the Tien Shan. Paths crossing the Tarim Basin are all efficient. A few paths from eastern Tibet show efficient Sn propagation, but the majority of events in Tibet do not show Sn. The Mongolian Plateau does not allow Sn to propagate either. Lack of efficient Sn propagation beneath these plateaus indicates that the uppermost mantle beneath them may be partially melted; possibly analogous with the mantle beneath the Turkish-Iranian Plateau or the Basin and Range Province (Hearn & Ni, 1994; Rodgers et al, 1995). Lg is observed for most raypaths, especially those ray paths that cross Mongolia, Tien Shan and Tarim Basin. Only a few of the longer paths from Tibet have Lg completely eliminated.

For station LZH (Lanzhou; Figure 4), Sn is observed for those crustal events originating from the Tarim Basin and the southern Tien Shan. Most events north and east of the station also show good Sn; however, there are a few events occurring in eastern China that also show no Sn. Events crossing Tibet from the southwest also have no Sn. Lg is observed from northern China events with epicentral distances less than about 10 degrees. Lg records for rays originating at all azimuths except the southwest azimuth (eastern Tibet). For those ray paths traversing a large portion of western Tibet, Lg is no longer observed.

For station BJI (Beijing; Figure 5), Sn is only observed for some nearby events. This is probably due to the fact that BJI is located in the eastern China rift system which may be underlain by an attenuated upper mantle. In contrast to Sn, Lg propagates efficiently from all the events we looked at.

For station MDJ (Mudnjiang; Figure 6), in northeast China, Sn is weak for events occurring near Lake Baikal and is not seen from events in Mongolia or north-central China. Sn is almost never detected from any of the many western Pacific events. Lg propagates efficiently to station MDJ from all continental paths, but is fully attenuated for all west Pacific events. This is consistent with other observations that have repeatedly shown Lg to be attenuated when crossing any oceanic crust.

For station QIZ (Qiongzhong; on Hainan Island; Figure 7), Sn is not observed for those ray paths crossing Indochina. In late Cenozoic, a large part of the Indochina is a back-arc and the uppermantle may still be hot there. Thus, the observed Sn propagation is consistent with known geology. Sn is also not usually seen for events in the west Pacific (Philippines and Borneo) although a few events with weak Sn do arrive from near Taiwan. Lg is seen from earthquake travel from Taiwan; these events travel beneath the continental shelf and do not cross any oceanic crust. Events that do lie across oceanic crust (Philippines and Borneo) always have Lg completely extinguished. Lg propagates weakly from paths that traverse Burma and most of the Indochina.

Station KMI (Kunming; Figure 8), sees Sn only from paths from eastern China, but all other paths (from Tibet and Indochina) do not have Sn. This is most likely due to the attenuation associated with the eastern China rift system. Lg is seen from nearly all azimuths at this station, but longer Lg raypaths (>10 degrees) are more attenuated.

Station TLY (Talaya; Figure 9), at the southern end of Lake Baikal, has paths that travel along Lake Baikal or cross Mongolia. All of these paths have no Sn propagation but do have efficient Lg propagation. We suspect that the Sn phase may be attenuating due to partial melt

within the uppermost mantle beneath the Baikal Rift and beneath the Mongolian Plateau. Lg propagates efficiently since there are no major changes in crustal thickness for any of these paths.

Conclusions and Recommendations

The northern Tibet Plateau seems to attenuate most Sn, but southern and eastern Tibet often have weak, but visible, Sn propagation. This zone of Sn attenuation roughly corresponds to a zone of low Pn velocity in central Tibet (e.g., Zhao and Helmberger, 1992). Sn also does not propagate efficiently beneath the Mongolian Plateau, southeast China, the Baikal Rift, the east China Rift, and Indochina. Events occurring on the Pacific Rim also lack the Sn phase. Paths of efficient Sn propagation exist in central China (near station LZH), in northeast China, and within the Tarim Basin and the Tien Shan. With some notable exceptions, we observe, then, that Sn seems to be attenuated for most tectonically active regions (Tibet, Mongolia, Indochina, the east China Rift, and the west Pacific), while it is not attenuated within the more stable regions of eastern China. Since Sn is often attenuated where Pn velocities are low, we conclude that a small amount of partial melt within the mantle may be responsible for much of the Sn attenuation within Asia. Alternatively, a very thin mantle lid with a negative S-velocity gradient could also diminish Sn.

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The Sn data in China is sufficiently large now and we plan to do a Sn tomography map for this geologically very interesting region. We are also planning to compare the Sn attenuation results to apparent Pn velocities in the region. The Lg data set is also suited for a tomographic study of Lg attenuation in China.

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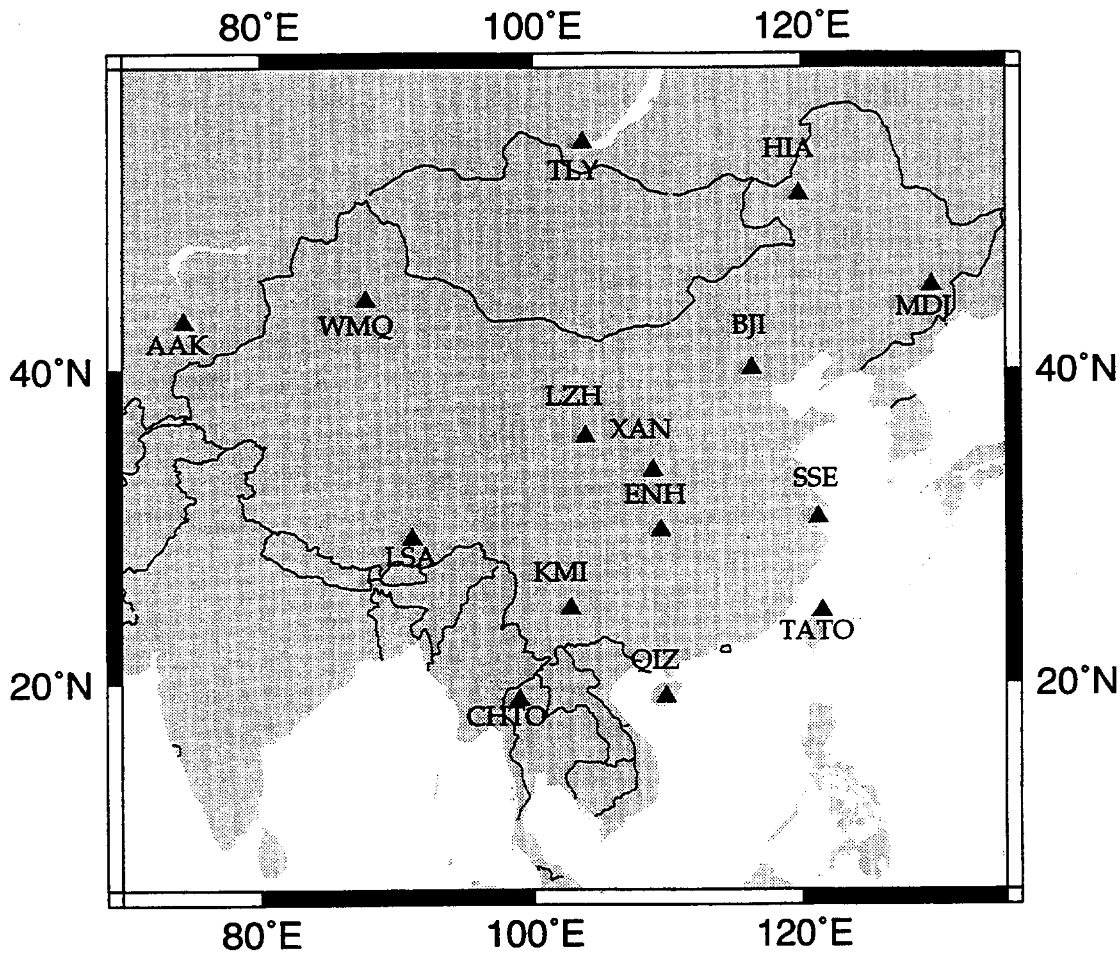

Figure 1. Locations of seismic stations in and around China.

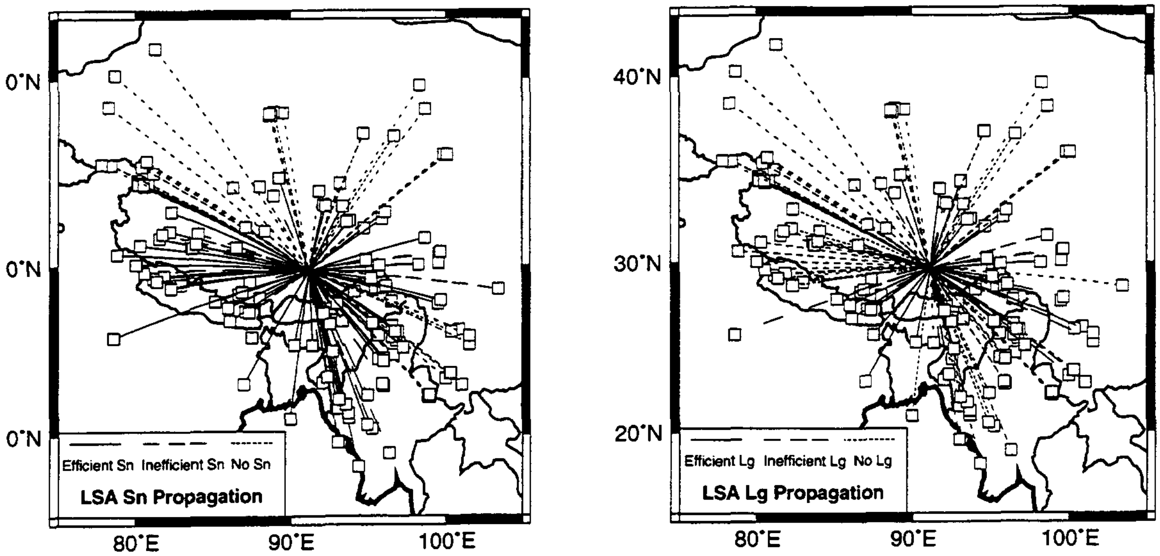

Figure 2. Sn and Lg propagation efficiencies for station LSA (Lhasa).

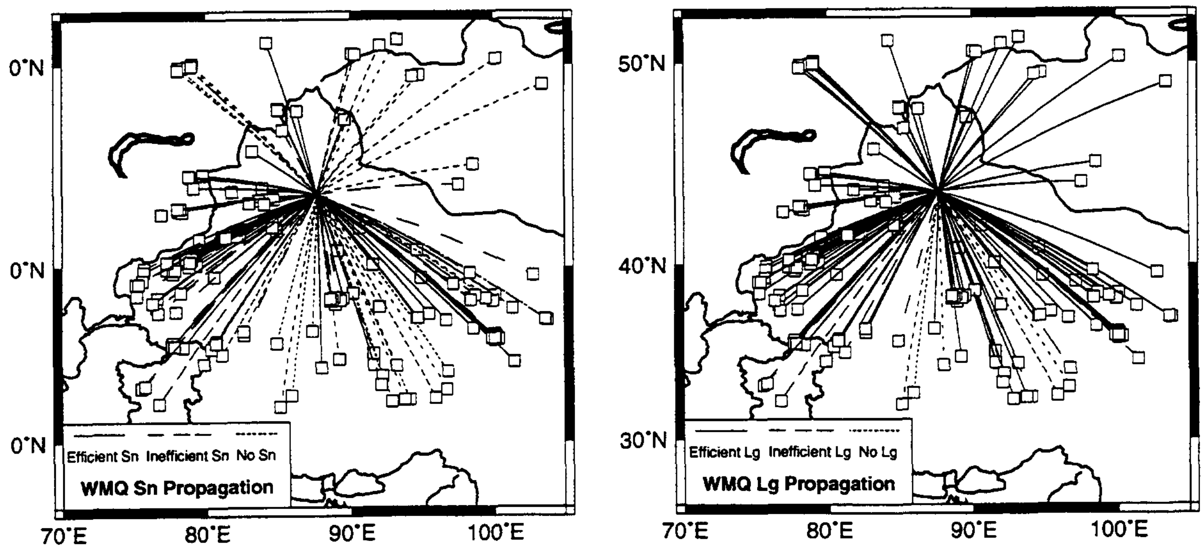

Figure 3. Sn and Lg propagation efficiencies for station WMQ (Urumqi).

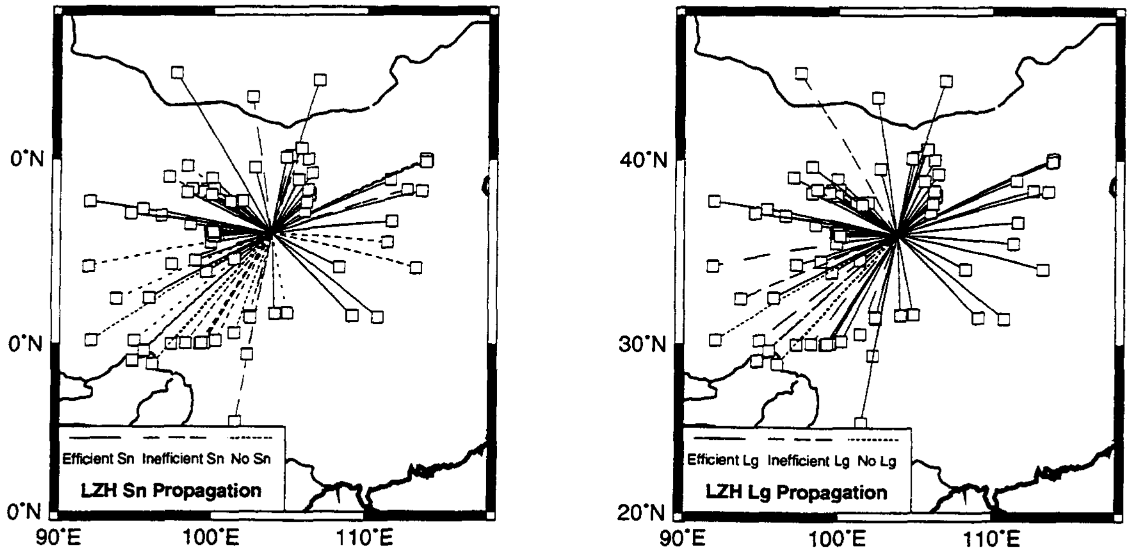

Figure 4. Sn and Lg propagation efficiencies for station LZH (Lanzhou).

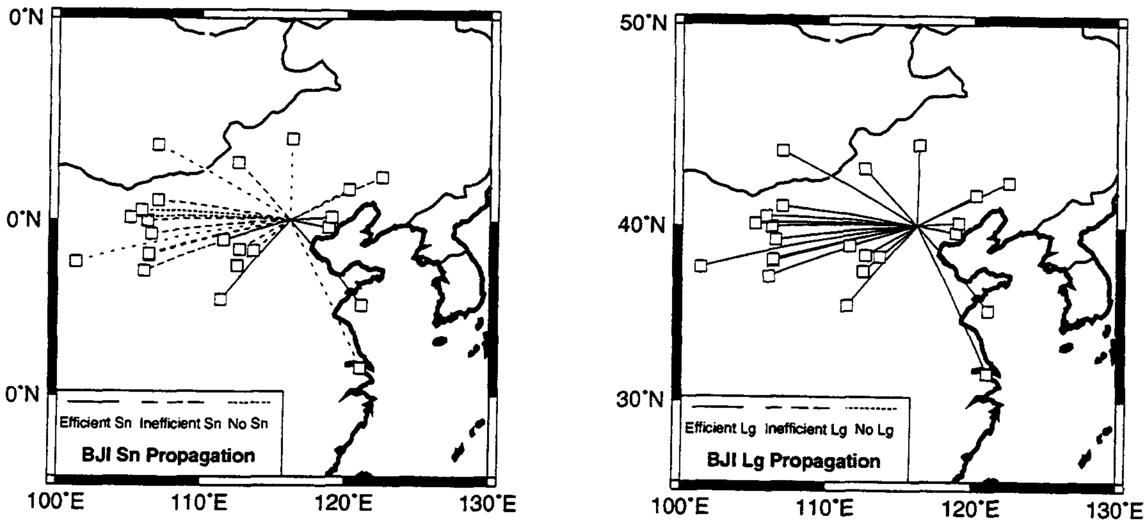

Figure 5. Sn and Lg propagation efficiencies for station BJI (Beijing).

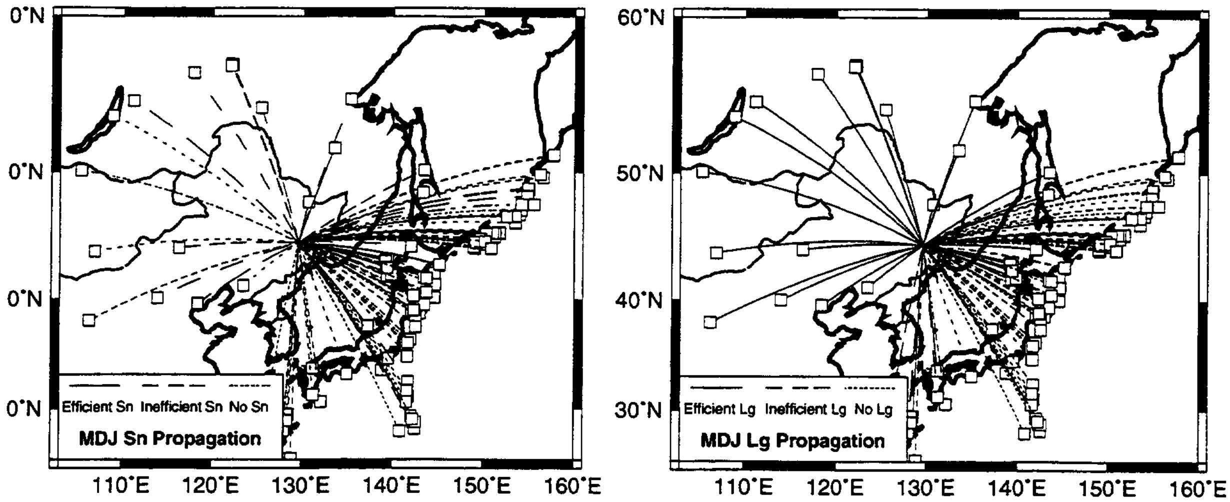

Figure 6. Sn and Lg propagation efficiencies for station MDJ (Mudanjiang).

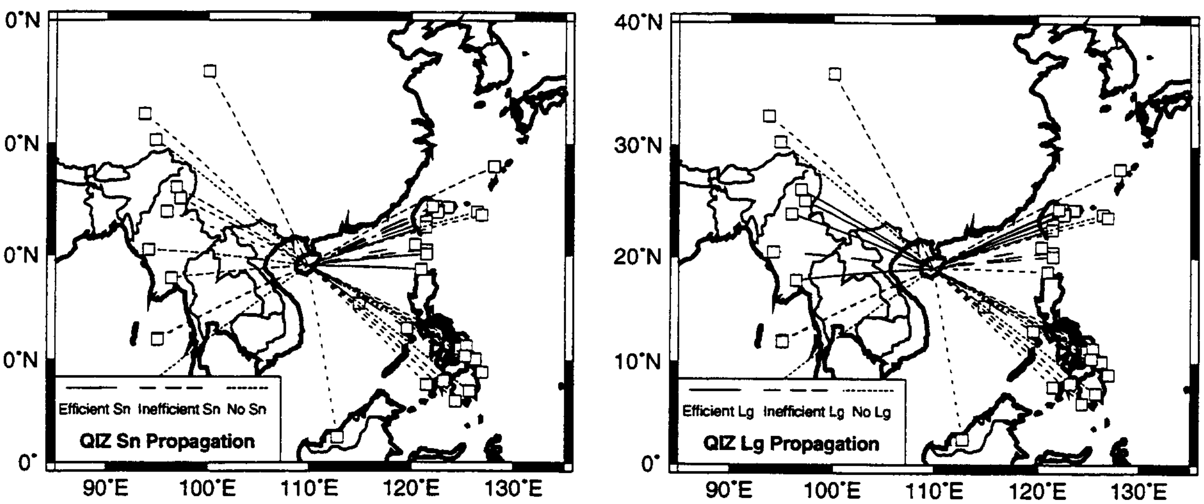

Figure 7. Sn and Lg propagation efficiencies for station QIZ (Qiongzhong).

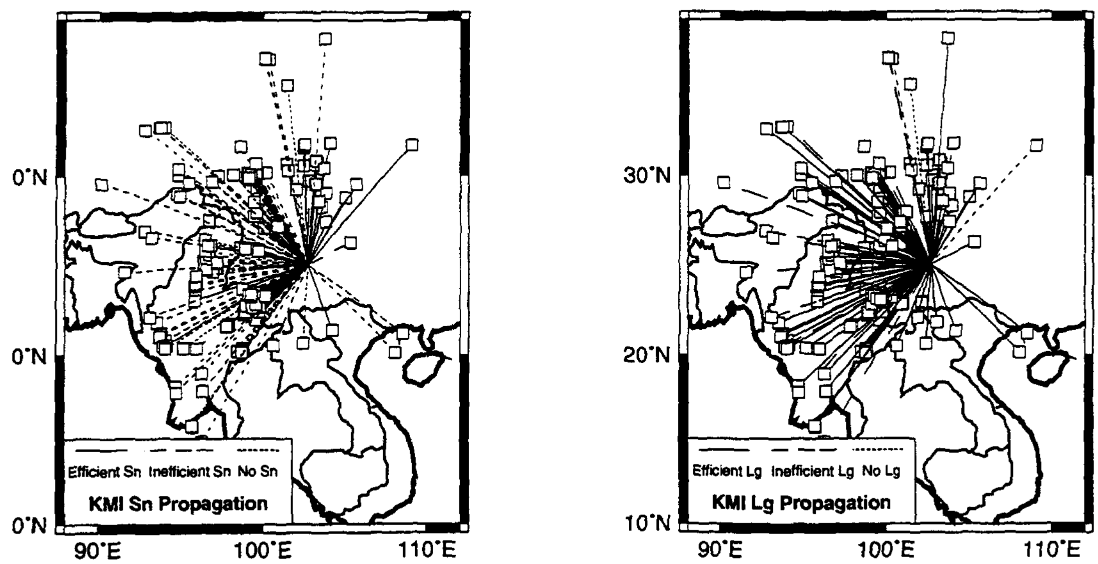

Figure 8. Sn and Lg propagation efficiencies for station KMI (Kunming).

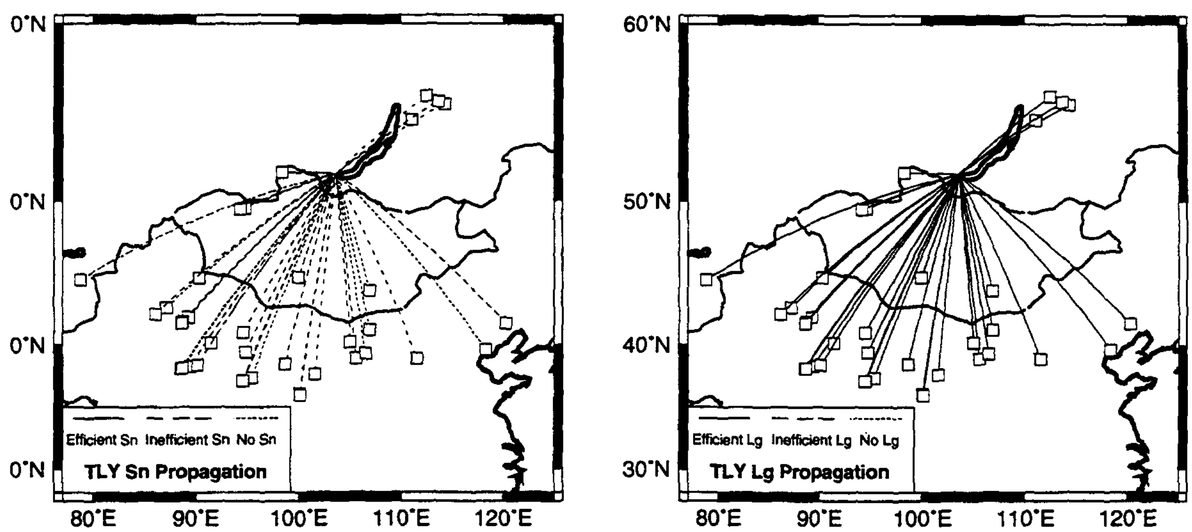

Figure 9. Sn and Lg propagation efficiencies for station TLY (Talaya).